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# LIQUID NITROGEN AND WATER JET MILLING OF ENERGETIC MATERIAL PRODUCTION WASTES

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## EXECUTIVE SUMMARY

U.S. Army Ammunition Plants (AAPs) and Load, Assemble and Pack (LAP) facilities generate pyrotechnic, explosive and propellant (PEP) production wastes of diverse nature. These production wastes can be in the form of "off-spec" energetic material (EM), EM contaminated with foreign substances, or processing equipment and materials contaminated with EM. At most of the facilities, these heterogeneous wastes are destroyed or mineralized by open burning/open detonation (OB/OD), a practice which is scrutinized and restricted because of environmental contamination concerns.

. In recent years several alternative technologies to OB/OD have been identified and developed which can process heterogeneous production wastes to ultimate destruction safely. An eclectic approach to the production waste disposal problem has been used based upon the understanding that no single "clean" technology can replace OB/OD. Controlled incineration (CI), wet air oxidation (WAO), hydrothermal oxidation (HTO) and composting have been evaluated and assessed for applicability and efficacy. Each of these alternative destruction technologies for OB/OD require the energetic materials to be reduced to a size compatible with the feed system of the destructor.

Because EM production wastes at Army ammunition plants (AAPs) can be contaminated with tramp metals, rocks, glass, wood and other extraneous matter, conventional metal bladed grinding or shearing equipment cannot be safely used to effect diminution. Thus the question is, how can we safely cut up contaminated EM production wastes, without the use of metal bladed equipment? One solution is hydromilling.

Hydromills are devices which use high pressure waterjets, operating at up to 385 MPa (55,000 psi), as the cutting tools. During FYs 94 and 95, USACERL engineers in collaboration with engineers at the Lonestar AAP (LSAAP), the Radford AAP (RAAP) and Flow International, Inc. designed, constructed and field tested six different prototypes of high pressure waterjet hydromills for the diminution of energetic materials (EM) and energetic material contaminated wastes (EMCW). The hydromills have been designated the X-Y Table, Cone-Cylinder I, Cone-Cylinder II, Tiered Rotosieves, Cylindrical Rotobasket and Drum Mill. The Drum Mill, the last hydromill to be designed, built, and tested, incorporates the best features of its predecessors and has been selected for continued development and use in FY96 research efforts at LSAAP.

The fundamental effectiveness of high pressure waterjets to cut energetic materials was evaluated early in the research using the X-Y Table hydromill. The X-Y Table is a "batch reactor" which employs a set of three rastering high pressure waterjets. During operation, the jets make multiple perpendicular sets of parallel cuts in the EM, which rests on top of a wire mesh platen or table. Blocks of Composition A5, Composition B, PBX-0280 and TNT, as thick as 6.5cm, were readily and safely cut with 0.18 - 0.25 mm diameter waterjets, operating at 280-385 MPa. Samples of Benite, M900 tracer composition and the two propellants M31A1E1 and NOSIH-AA2 were also readily processed with the X-Y Table hydromill. Because the X-Y Table hydromill needed to be loaded and unloaded by hand, design efforts were redirected towards the development of a mill which would

function as a continuous flow reactor. The Cone-Cylinders and the Tiered Rotosieves each had good design features, and could serve as a continuous flow reactor, but did not function as well as expected. The Cylindrical Rotobasket was another batch reactor with feed limitations, but its excellent cutting performance suggested that an earlier considered concept of a rotating drum mill was viable.

Our prototype Drum Mill, which is currently installed in a test bay at the LSAAP, comprises a modified 55 gallon stainless steel drum, which rotates at 2 rpm about its longitudinal axis while supported on a motor driven, rubber-wheeled drum roller and has an interior waterjet manifold. The drum roller and drum are on an angle-iron frame which is inclined at 15°from the horizontal. In this orientation, the Drum Mill resembles a concrete mixer. The feed end of the drum is above the discharge end, which allows gravity assisted movement of the EM within the drum. A rubber wheel, which rolls along a circumferential track at the base of the drum, at the discharge end, serves as a thrust bearing to keep the freely rotating drum properly positioned on the drum roller. The high pressure water manifold has eleven waterjets, each with a 0.15 mm diameter orifice. The jets are spaced evenly along the 82 cm long manifold. The high pressure water for the jets is provided by a Flow International 20X pump, with dual intensifiers and capable of delivering 385 MPa water at 7.6 liters/min. The waterjets point downward towards the interior cylindrical surface of the drum. The manifold is parallel with and attached to a metal rod which moves a short distance in and out, along the length of the drum. This cyclic movement is driven pneumatically. The waterjet manifold is inclined from the discharge end to the feed end at 10° with respect to the side of the cylindrical drum. This allows the waterjets to be at a decreasing standoff from the drum surface as EM moves down the length of the drum. This arrangement accommodates initially large feed and ensures the waterjets get closer to the drum as the EM cuttings gets smaller and smaller. Positioned at three locations along the length of the cylinder is a circumferential merloned-crenelated fence. The height and gap spacing of the three fences decreases from the feed to discharge end. The fences serve to restrict the movement of the solids through the mill, providing an increase in the residence time and therefore cutting effectiveness for the waterjets. The right cylinder portion of the stainless steel drum is 87 cm long and 59 cm OD. A stainless steel cowling at the mill's inlet adds an additional 13 cm to the overall length. The Drum Mill has cut Composition B and PBX-0280, reducing 1-3 kg blocks of the high explosives to kidney bean size chips in minutes. In a continuous flow mode, it is expected the prototype Drum Mill will process about 30 kg/hr.

The high pressure waterjet Drum Mill will quickly and safely reduce the size of diverse EM production wastes providing feed stock suitable for environmentally benign destruction.

In lieu of water, a novel system which uses high pressure liquid nitrogen ($LN_2$) has been developed at the Idaho National Engineering Laboratory (INEL) to perform cutting and abrading, without the introduction of a secondary waste stream of cutting media. This cryomill is referred to as ZAWCAD, an acronym for Zero Added Waste Cutting, Abrading and Drilling.

The ZAWCAD is similar to abrasive waterjet cutting systems in appearance and function, although the nozzle assembly through which the $LN_2$ flows is more complex. The working fluid, $LN_2$, is pressurized to 420 MPa (60,000 psi) and ejected through a small orifice at a flow rate of 0.5-10 liters/min, depending upon the orifice diameter and fluid pressure. The velocity of the stream has been measured at greater than 900 m/s (3,000 ft/s) near the output of the nozzle. In bulk quantities, the $LN_2$ can be purchased for as little as 6 cents per liter.

The ZAWCAD developers have cut foam-insulation, foodstuffs and ferrous metals and recently, in collaboration with USACERL personnel, have successfully employed the cryomill for the cutting of Composition A5, Composition B, TNT, Benite, M31A1E1 and NOSIH-AA2. A 0.2 mm orifice was employed for the cutting of all EM. The feed rate of energetics into the $LN_2$ jet was 6 mm/s. Because the $LN_2$ "cutting fluid" rapidly vaporizes moments after leaving the site of erosive action, the only waste stream from the ZAWCAD is a "dry sawdust" of the material cut. This is, however, a mixed blessing. While no water or other liquid solvent waste stream needs to be subsequently processed for environmentally benign disposal, the dry sawdust (finely powdered EM) from the ZAWCAD does represent a potential explosive hazard, but is definitely manageable.

The ZAWCAD cryomill is a system which clearly warrants continued research and development as a promising technology for both the pretreatment of EM production wastes and the machining (cutting, abrading, milling and drilling) of energetic materials.